THE MEAN RIGHT ASCENSIONS AND PROPER MOTIONS OF 130 STARS

BY

EDITH D. KAST

A THESIS

PRESENTED TO THE FACULTY OF PHILOSOPHY OF THE UNIVERSITY OF PENNSYLVANIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

PRESS OF
THE NEW ERA PRINTING COMPANY
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THE MEAN RIGHT ASCENSIONS AND PROPER MOTIONS OF 130 STARS.

The stars whose right ascensions and proper motions are discussed in this paper are the stars now used by Prof. C. L. Doolittle in his investigation of the variation of latitude at the Flower Observatory of the University of Pennsylvania. For his work the declinations of these stars have been reduced in the same way as the right ascensions are in this paper. With Prof. Doolittle's permission the data of the declinations and the results of that investigation are given for the sake of completeness in this.

THE CATALOGS.

The following catalogs were employed as the basis of the reduction. For all catalogs for which Boss* gives systematic corrections and weights these have been used. In other cases such corrections and weights have been derived indirectly through Auwers'† system but Auwers' weights have been multiplied in right ascension by .694 and in declination by 1.414 to bring them more nearly into accordance with Boss' weights. For a few, weights were derived through Davis'‡ assignment by comparing with catalogs common to both Boss and Davis. In a few cases, special methods were used which are designated in the explanatory notes that accompany.

In these notes s designates the systematic correction in right ascension, s' that in declination, p the weight in right ascension and p' that in declination.

1. Bradley. 1755. Neue Reduction der Bradleyschen Beobachtungen aus den Jahren 1750 bis 1762. Von Arthur Auwers. St. Petersburg, 1888.

2. Lalande. 1800. A Catalogue of those Stars in the Histoire Céleste Française of Jérôme de Lalande for which tables of reduction to the epoch 1800 have been published by Prof. Schumacher. Francis Bailey, Esq. s and s' same as 4. Very small weights were given Lalande's places. t was taken from the Paris catalogs.

3. D'Agelet. 1800. Reduction of the Observations of Fixed Stars made by Joseph Lepante d'Agelet at Paris in 1783–1785 with a catalog of the Corresponding Mean Places referred to the equinox of 1800.0. By B. A. Gould. Washington, 1866.

$s = 0^s.12$ + reduction from Auwers to Boss

$s' =$ Piazzi $- 1''.42$ $\quad 0^h$ to XII^h

$s' =$ Piazzi $+ 1''.22$ $\quad XII^h$ to $XXIV^h$

* Cf. *Astronomical Journal*, Nos. 549–550.

† For the reduction to Auwers' system cf. Auwers' "Tafeln zur Reduction von Sterncatalogen auf das System des Fundamentalcatalogs des Berliner Jahrbuchs" published as Supplement No. 7 to *Astronomische Nachrichten*, also *Ast. Nach.*, Bd. 134, Nos. 3195–3196 for a few other catalogs. For the reduction from Auwers' system to Boss' cf. *Ast. Journal*, v. 23, p. 22. For Auwers' weights cf. *Ast. Nach.*, Bd. 151, No. 3615.

‡ Cf. "Declinations and Proper Motions of Fifty-six Stars."

4. Piazzi. 1800. Præcipuarum stellarum inerrantium Positiones Mediæ Ineunte Sæculo XIX ex observationibus habitas in Specula Panormitana ab anno 1792 ad annum 1813. Panormi, 1814.

5. Groombridge. 1810. A catalog of Circumpolar Stars deduced from the observations of Stephen Groombridge at Blackheath Observatory. Edited by George Biddell Airy, Esq. London, 1838. The new reduction of Groombridge by Dyson and Thackeray of the Royal Observatory, Greenwich, came after the work was finished but the reduction in declination was revised for those stars whose place in the new differed more than .5″ from that in Airy's. For Airy's s' as in Boss' Declinations of Fixed Stars. U. S. Northern Boundary Commission. Report of the Chief Astronomer. Appendix H.

6. Dorpat. 1815.

7. Weisse-Bessel. 1825. Bessel's zone observations reduced by Maximillian Weisse. $p = .1$, $s' = 0$.

8. Auwers' Königsberg. 1825. Auwers' reduction of some newly found zone observations made by Bessel. The reduction based on Auwers' system.

9. Abo. 1830. DLX Stellarum Fixarum Positiones Mediæ ineunte anno 1830 ex observationibus Aboæ habitas deduxit. Fredr. Guil. Aug. Argelander. Helsingforsiæ, 1835.

10. Struve. 1830. Stellarum Fixarum imprimis duplicium et multiplicium pro epocha 1830. Petropli, 1852.

11. Struve. 1832.

12. Struve. 1836. s, s', p and p' as for Dorpat, 1830.

13. Madras. 1835. A General Catalog of the Principal Fixed Stars from Observations made at the Honorable East India Company's Observatory at Madras in the years 1830 to 1843. By Thomas Glanville Taylor. Madras, 1844.

14. Rümker. 1836. Mittlere Oerter von 12,000 Fixsternen für den Anfang von 1836, abgeleitet aus den Beobachtungen auf der Hamburger Sternwarte von Carl Rümker. Hamburg, 1852.

15. Armagh. 1840. Places of 5345 Stars observed from 1828 to 1854 at the Armagh Observatory. By Rev. T. R. Robinson. Dublin, 1859.

16. Greenwich. 1840. Catalogue of 2156 Stars formed from the Observations made from 1836 to 1841 at the Royal Observatory, Greenwich. London, 1849.

17. Oeltzen's Argelander. 1842. Annalen der K. K. Sternwarte in Wien. Bd. 1. Wien, 1851. s, s', p and p' same as for Abo.

18. Greenwich. 1845. Catalogue from Observations from 1842 to 1847.

19. Paris. 1845. Catalogue de l' Observatoire de Paris. Étoiles observées aux Instruments Méridiens de 1837 à 1853.

20. Radcliffe. 1845. The Radcliffe Catalogue of 6317 Stars, chiefly Circumpolar reduced to the Epoch 1845. Formed from the Observations made at the Radcliffe Observatory under the Superintendence of Manuel John Johnson. Oxford, 1860.

21. Gilliss. 1850. A Catalogue of 1963 Stars and of 290 Double Stars observed by the U. S. Naval Astronomers during the Expedition to the Southern Hemisphere. Appendix 1 to Washington Yearly Observations for 1868.

22. Greenwich. 1850. Catalogue of 1576 Stars formed from Observations made during Six Years, from 1848 to 1853, at the Royal Observatory, Greenwich.

23. Madras. 1850. A Subsidiary Catalogue of 1440 Stars selected from the British Asso-

ciation Catalogue, reduced to Jan. 1, 1850, from Observations made at Madras in the years 1849 to 1853. Madras, 1854.

24. SONNTAG. 1850. Mittlere Oerter für 1850 von Vergleichsternen zum Cometen I 1850. *Ast. Nach.*, Bd. XXXIV. p same as 19; $s = .050$ + reduction from Auwers to Boss; s' as in Auwers for Busch 1838 + reduction from Auwers to Boss.

25. WROTTESLEY. 1850. A Catalogue of the Right Ascentions of 1009 Stars contained in the Catalogue of the British Association for the Advancement of Science. By Lord Wrottesley. Memoirs R. A. S., Vol. XXIII. Based on Nautical Almanac.

26. ALTONA. 1855. s and s' as for Sonntag 1850.

27. POULKOVA. 1855. Positions Moyenne déduites des observations faites au cercle méridien 1840–1869 et réduites à l'époque 1855.0. Observations de Poulkova, Vol. VIII. St. Petersburg, 1889.

28. GREENWICH. 1860. Seven Year Catalogue of 2022 Stars deduced from Observations extending from 1854 to 1860 at the Royal Observatory, Greenwich.

29. PARIS. 1860. Catalogue de l'Observatoire de Paris. Étoiles observées de 1854 à 1867.

30. RADCLIFFE. 1860. Second Radcliffe Catalogue, containing 2386 Stars deduced from observations extending from 1854 to 1861 - - - . Oxford, 1870.

31. YARNALL. 1860. Catalogue of Stars Observed at the United States Naval Observatory during the years 1845 to 1877. Third edition revised - - - . Washington, 1889.

32. GREENWICH. 1864. New Seven Year Catalogue of 2760 Stars, deduced from Observations extending from 1861 to 1867 at the Royal Observatory, Greenwich.

33. BRUSSELS. 1865. Catalogue de 10,792 Étoiles observées à l'Observatoire Royal de Bruxelles de 1857 à 1878 - - - . Par Ernest Quetelet. Bruxelles, 1887.

34. POULKOVA. 1865. Ascensions droites Moyenne des Étoiles occasionnellement observées pour 1865.0. Observations de Poulkova, Vol. XII.

35. GLASGOW. 1870. Catalogue of 6415 Stars for the Epoch 1870, deduced from Obsert vations made at the Glasgow University Observatory during the Years 1860 to 1881. By Rober-Grant. Glasgow, 1883.

36. GREENWICH. 1872. Nine Year Catalogue of 2263 Stars deduced from Observations extending from 1868 to 1876, made at the Royal Observatory, Greenwich.

37. BONN. 1873. (One observation from this was taken from Küstner's Veröffentlichung der Königlichen Sternwarte zu Bonn, No. 2, but Bonn 1873 was not found.)

38. ASTRONOMISCHE GESELLSCHAFT ZONES. 1875. These include all of this series between 26° and 53°. p and p' taken as 1.0. Based on Auwers' system.

39. ARMAGH. 1875. Second Armagh Catalogue of 3300 Stars for the Epoch 1875, deduced from Observations made at the Armagh Observatory during the Years 1859 to 1883. Dublin, 1886.

40. BECKER. 1875. Resultate aus Beobachtungen von 521 Bradley'schen Sternen am grossen Berliner Meridiankreise von Dr. E. Becker. Berlin, 1881. Based on Auwers'.

41. KAM. 1875. Catalog von Sternen deren Oerter durch selbständige Meridian Beobachtungen bestimmt worden sind aus Band 67 bis 112 der *Ast. Nach.* reducirt auf 1875.0. Amsterdam, 1901. The original observations were looked up and given such weights as seemed best in each case.

42. WASHINGTON. 1875. The Second Washington Catalogue of Stars - - - prepared under the Direction of J. R. Eastman.

43. PARIS. 1875. Catalogue de l'Observatoire de Paris. Étoiles observées de 1868 à 1881.

44. Poulkova. 1875. Catalog von 5634 Sternen für die Epoche 1875.0, aus den Beobachtungen am Pulkowaer Meridiankreise während der Jahre 1874–1880 von H. Romberg. St. Pétersbourg, 1891.

45. Stockholm. 1875. Results of Meridian observations found in the first five volumes of the publications of the Stockholm Observatory. p and p' same as 43. Based on Auwers' system.

46. Respighi. 1875. Catalogo delle Declinazione Medie pel 1875.0 di 1463 Stelle comprese fra i paralleli 20° e 64° nord - - - - . Roma, 1880.

47. Greenwich. 1880. Ten Year Catalogue of 4059 Stars, deduced from Observations extending from 1877 to 1886 at the Royal Observatory, Greenwich.

48. De Ball. 1880. Declinationen von 200 Sternen innerhalb der Zone, + 49° bis 51°, nach Beobachtungen im ersten Vertical am Passagen-instrumente der Herzoglichen Sternwarte zu Gotha. *Ast. Nach.*, Bd. ci, 353. s and s' reduction from Auwers' to Boss'.

49. Cape of Good Hope. 1890. A Catalogue of 3007 Stars for the Equinox 1890 from Observations made at the Royal Observatory, Cape of Good Hope, during the years 1885 to 1895.

50. Cincinnati. 1890. A Catalogue of 2000 Stars for the Epoch 1890. Publications of the Cincinnati Observatory, No. 13. Based on Auwers' system.

51. Dunsink. 1890. Mean Places of 717 Stars deduced from Observations made with the Meridian Circle at Dunsink. Dublin, 1896. p and p' same as 50. s and s' the reduction from Auwers' to Boss'.

52. Glasgow. 1890. Second Glasgow Catalogue of 2156 Stars for the Epoch 1890 deduced from Observations made at the Glasgow University Observatory during the Years 1886 to 1892. Glasgow, 1892.

53. Greenwich. 1890. Catalogue of Stars from Observations extending from 1887 to 1896.

54. Berlin. 1890. (Küstner refers to several of these in Veröffentlichung der Königlichen Sternwarte zu Bonn, No. 2. They were his own observations but I could find them nowhere else.)

55. Radcliffe. 1890. Catalogue of 6424 Stars for the Epoch 1890. Formed from Observations made at the Radcliffe Observatory, Oxford, during the Years 1880 to 1893.

56. Battermann. 1895. Resultate aus Beobachtungen von 379 Anhaltsternen und 1640 durch Anschluss bestimmten Sternen, angestellt in den Jahren 1892–1897 am Grossen Berliner Meridiankreise von Dr. H. Battermann. Berlin, 1899. s and s' the reduction from Auwers' to Boss'.

57. Cincinnati. 1895. Catalogue of 2030 Stars for the Epoch 1895. Publications of the Cincinnati Observatory, No. 14. s and s' the reduction from Auwers' to Boss'.

58. Tucker. 1897. Publications of the Lick Observatory, Vol. VI, Meridian Circle. $p' = 3.0$.

59. Cincinnati. 1900. Reobservations of more than 4000 Piazzi stars. Based on Auwers'.

60. Dunsink. 1900. Mean Places of 1101 Stars deduced from Observations made with the Meridian Circle at Dunsink. p, p', s and s' as for 51.

61. Küstner. 1900. Veröffentlichung der Königlichen Sternwarte zu Bonn. Nos. 5 and 6. s and s' the reduction from Auwers' to Boss'.

62. Washington. 1901. Observations made in the prime vertical by Prof. Hill. $s' = 0$, $p' = 5.0$.

63. Lick Observatory. 1906. Observations made by Tucker. Based on Newcomb's system. s and s' reduction from Newcomb to Boss; $p = 5.0$, $p' = 5.0$.

Yearly Series.

64. 1835 to 1869. Edinburg. Astronomical Observations at the Royal Observatory, Edinburg. Only a few of these places were used. s' as in Boss' Declinations of Fixed Stars.

65. 1862 to 1876. Radcliffe. Results of Astronomical Observations made at the Radcliffe Observatory. s, p and p' same as Radcliffe, 1860; s' from 1867 to 1873 from Boss' Declinations of Fixed Stars; s' from 1874 to 1876 the mean of reductions for 1871, 1872 and 1873.

66. 1862 to 1887. Madras. Meridian Circle Observations.

67. 1879 to 1882. Brussels. Annales de l'Observatoire Royal de Brusselles, Nouvelle Series. s and s' same as for Nautical Almanac.

METHOD OF REDUCTION.

Approximate places for 1875.0 were obtained and with these the differential coefficients for 1875 were computed, using the constants of Struve and Peters. The formulæ for these differential coefficients are as follows:

$$\frac{d\alpha}{dt} = 3^s.07225 + [0.126\ 115] \sin\alpha \tan\delta + \mu$$

$$\frac{d\delta}{dt} = [1.302\ 206] \cos\alpha + \mu'$$

$$\frac{d\mu}{dt} = [5.988]\ \mu \cos\alpha \tan\delta + [4.812]\ \mu' \sin\alpha \sec^2\delta + [4.99]\ \mu\mu' \tan\delta$$

$$\frac{d^2\alpha}{dt^2} = [4.63380_n]\left(\frac{d\alpha}{dt} - \mu\right) + [5.98778]\left(\frac{d\alpha}{dt} + \mu\right)\cos\alpha \tan\delta + [4.81169]\left(\frac{d\delta}{dt} + \mu'\right)\sin\alpha \sec^2\delta$$
$$+ [4.9866]\mu\mu' \tan\delta + 0^s.000\ 032\ 210$$

$$\frac{d^2\delta}{dt^2} = [4.63380_n]\left(\frac{d\delta}{dt} - \mu'\right) + [7.16387_n]\left(\frac{d\alpha}{dt} + \mu\right)\sin\alpha + [6.7367_n]\,\mu^2 \sin 2\delta$$

$$\frac{d^3\delta}{dt^3} = [2.0987]\left(\frac{d\alpha}{dt} + \frac{\mu}{2}\right)\sin\alpha + [7.1639_n]\left(\frac{d^2\alpha}{dt^2} + \frac{d\mu}{dt}\right)\sin\alpha + [3.0255_n]\left(\frac{d\alpha}{dt} + \mu\right)\frac{d\alpha}{dt}\cos\alpha$$

where the numbers enclosed in brackets are logarithms

α = the right ascension,
δ = the declination,
μ = proper motion in right ascension,
and μ' = proper motion in declination.

For calculating $d^3\alpha/dt^3$ the tables of Oppolzer were used (Lehrbuch zur Bahnbestimmung der Kometen und Planeten, Vol. I, Table XII) which, because of the small zenith distances of all the stars on the list, were sufficiently accurate. For checking these values use was made of Gould's Tables*; for checking the other differential coefficients Oppolzer's Tables were used.

* Catálogo de Las Zonas Estelares, Appendix, Table IV. Cordoba, 1884. In using this table the value of p^3 as given in column four should be doubled. Cf. *Ast. Nach.*, Bd. 137, s. 295.

Then the assumed places for 1875.0 were reduced to the epochs of the various catalogs in which the star was found, making use of the formulæ

$$\alpha = \alpha_{1875} + \frac{d\alpha}{dt}(T - 1875) + \frac{1}{2}\frac{d^2\alpha}{dt^2}(T - 1875)^2 + \frac{1}{6}\frac{d^3\alpha}{dt^3}(T - 1875)^3$$

$$\delta = \delta_{1875} + \frac{d\delta}{dt}(T - 1875) + \frac{1}{2}\frac{d^2\delta}{dt^2}(T - 1875)^2 + \frac{1}{6}\frac{d^3\delta}{dt^3}(T - 1875)^3$$

where T = epoch of the catalog.

If in the catalog in question proper motion was assumed in deriving the star's place, there is need of applying a correction for proper motion.

If T = epoch of the catalog

t = mean date of observation

μ_0 = proper motion used in the catalog

μ = proper motion assumed in this investigation

then the correction $\Delta_\mu\alpha = (T - t)(\mu - \mu_0)$.

Comparing the catalog place, corrected by the systematic correction and the correction for proper motion, with the assumed place, carried back as explained to the epoch of the catalog we get an equation of the form

$$\Delta\alpha + \Delta\mu \cdot \tau = \alpha_{\text{observed}} - \alpha_{\text{computed}} = n$$

where $\Delta\alpha$ is the correction to our assumed right ascension,

$\Delta\mu$ the correction to our assumed proper motion and τ is the difference $1875 - t$.

Giving the equation such a weight as the catalog is thought to merit, it takes the form $\sqrt{p}(\Delta\alpha + \Delta\mu\tau = n)$ where p is the weight.

Each catalog will give such an equation and solving the system of equations so obtained for the star, by the method of least squares, the most probable values of $\Delta\alpha$ and $\Delta\mu$ will be determined.

The method of solving the system of equations was the following:

Let t_0 be the weighted mean of the epochs of observation of the various catalogs.

$t_1, t_2, \cdots t_n$ be the epochs of observation of the respective catalogs then

$$\tau_1, \tau_2, \cdots \tau_n = (t_1 - t_0), (t_2 - t_0), \cdots (t_n - t_0)$$

and $\Sigma p\tau$ should be zero.

$\Delta\alpha$ and $\Delta\mu$ are given by

$$\Delta\alpha = \frac{\Sigma pn}{\Sigma p} \quad \text{and} \quad \Delta\mu = \frac{\Sigma p\tau n}{\Sigma p\tau^2} \qquad \Delta\alpha_{1875} = \Delta\alpha + (1875 - t_0)\Delta\mu$$

The final check is

$$\Sigma pvv = \Sigma pnn - (\Sigma pn)\Delta\alpha - (\Sigma p\tau n)\Delta\mu$$

The following example will illustrate the various steps in the process.

$$t_0 = \frac{673.68}{9.65} = 69.81 \qquad \Sigma pv^2 = .0369$$

$= 1869.81$ $\qquad \Sigma pn^2 = .0455$

$\Delta\alpha = \dfrac{-.2337}{9.65} = -.0242$ $\qquad -(\Sigma pn)\Delta\alpha = -.0057$

$\Delta\mu = \dfrac{+4.1720}{6412.07} = +.00065$ $\qquad -(\Sigma p\tau n)\Delta\mu = -.0027$

$\Delta\alpha_{1875} = -.0242 + (.00065 \times 5.19) = -.0208$ $\qquad$ Check .0371

Assumed Coordinates and Proper Motions for 1875.0.

$\alpha = 17\ \ 49\ \ 13.980$ $\qquad \mu = +.0005$
$\delta = 40\ \ 1\ \ 57.56$ $\qquad \mu' = +.064$

No.	Catalog.	Epoch. Cat $=T$	Epoch. Obs. $=t$	No. Obs.	μ_0	$\mu - \mu_0$	$T-t$	$\Delta_\mu\alpha$	$\alpha_0-\alpha_s-\Delta_\mu\alpha$	$\alpha_0-\alpha_s$ n	p	pt	τ	$p\tau$	pn	pt^2	$p\tau n$	v
1	Bradley	1755	1755.6	1	+.0005	0000	− 0.6	000	−.046	−.046	.1	−4.44	−114.21	−11.42	−.0046	1304.16	+ .5253	−.052
2	Lalande	1800	93.6			+.0005	+ 6.4	+.003	−.356	−.353	.05	− .32	− 76.21	− 3.81	−.0176	290.32	+1.3411	+.279
3	Piazzi	00		10	−.03	+.0305			−.056	−.056	.1	0.00	− 69.81	− 6.98	−.0056	487.20	+ .3909	−.014
4	D'Agelet	00	1803.5			+.0005	− 3.5	−.002	−.189	−.191	.05	.18	− 66.31	− 3.32	−.0096	220.12	+ .6365	+.124
5	Groombridge	10	10.5	6		+.0005	− 0.5	000	+.087	+.087	.1	1.05	− 59.31	− 5.93	+.0087	351.65	− .5159	−.150
6	Madras	35	37.1	7		+.0005	− 2.1	−.001	−.277	−.278	.2	7.42	− 32.71	− 6.54	−.0556	213.86	+1.8181	+.232
7	Rümker	36	40.0	1		+.0005	− 4.0	−.002	−.189	−.191	.05	2.00	− 29.81	− 1.49	−.0096	44.40	+ .2861	+.147
8	Armagh	40	37.2	7		+.0005	+ 2.8	+.001	−.018	−.017	.2	7.44	− 32.61	− 6.52	−.0034	212.55	+ .1108	−.028
9	Edinburg	43	43.5	3		+.0005	− 0.5	000	−.107	−.107	.2	8.70	− 26.31	− 5.26	−.0214	138.34	+ .5628	+.066
10	Radcliffe	45	47.3	6		+.0005	− 2.3	−.001	−.064	−.065	.5	23.65	− 22.51	−11.26	−.0325	253.35	+ .7312	+.026
11	Paris	45	49.7	7		+.0005	− 4.7	−.002	+.054	+.052	.8	39.76	− 20.11	−16.09	+.0416	323.41	− .8362	−.089
12	Pulkova	55	51.8	4	+.0005	0000	+ 3.2	000	−.063	−.063	.5	25.90	− 18.01	− 9.00	−.0315	162.09	+ .5670	+.027
13	Yarnall	60	53.6	4		+.0005	+ 6.4	+.003	−.021	−.018	.4	21.44	− 16.21	− 6.48	−.0072	104.98	+ .1166	−.017
14	Paris	60	67.0	2		+.0005	− 7.0	−.004	−.162	−.166	.2	13.40	− 2.81	− 0.56	−.0332	1.57	+ .0930	+.140
15	Greenwich	64	66.3	3	−.004	+.0045	− 2.3	−.010	+.019	+.009	.6	39.78	− 3.51	− 2.11	+.0054	7.38	− .0189	−.035
16	Brussels	65	63.6	2		+.0005	+ 1.4	+.001	−.004	−.003	.2	12.72	− 6.21	− 1.24	−.0006	7.69	+ .0037	−.025
17	A. G.	75	89.5	6		+.0005	−14.5	−.007	−.010	−.017	1.0	89.50	+ 19.69	+19.69	−.0170	387.89	− .3349	+.006
18	A. G.	75	71.6		+.0005	0000	+ 3.4	000	+.031	+.031	1.0	71.60	+ 1.79	+ 1.79	+.0310	3.22	+ .0558	−.054
19	Romberg	75	78.7	2	+.0005	0000	− 3.7	000	+.005	+.005	.3	23.61	+ 8.89	+ 2.67	+.0015	23.76	+ .0134	−.023
20	Greenwich	80	86.3	4	+.0005	0000	− 6.3	000	−.050	−.050	1.2	103.56	+ 16.49	+19.79	−.0600	326.54	− .9894	+.036
21	Greenwich	90	95.9	3	+.0005	0000	− 5.9	000	+.006	+.006	.7	67.13	+ 26.09	+18.26	+.0042	476.59	+ .1096	−.013
22	Bonn	1900	98.5	2		+.0005	+ 1.5	+.001	−.019	−.018	.5	49.25	+ 28.69	+14.34	−.0090	411.56	− .2583	+.012
23	Cincinnati	1900	1900.5	3		+.0005	− 0.5	000	−.011	−.011	.7	70.35	+ 30.69	+21.48	−.0077	659.44	− .2363	+.007
											9.65	673.68		+ 0.01	−.2337	6412.07	+4.1720	

Final Values.

$\alpha = 17\ \ 49\ \ 13.959$
$\mu = +.00115$

The proper motions derived by this reduction were changed later by the necessary amount to pass over to Newcomb's constants from Struve and Peter's.

THE RESULTS.

The list of stars which follows includes 5 (N) found in Newcomb's Fundamental Catalog, and 1 (B) found in H. B. Evans' Mean Right Ascensions and Proper Motions of 254 Stars. The places of these have been taken from these sources and corrected by amounts necessary to reduce them to Boss' system and Newcomb's constants. There were also 5 (F. O.) Flower Observatory stars whose declinations had been previously determined by Prof. Doolittle and 1 (D) Davis star. The declinations of these six were taken from the sources indicated and the necessary corrections applied to bring them to Boss' system and Newcomb's constants. The differential coefficients $d\alpha/dt$ and $d\delta/dt$ include the proper motions μ and μ'.

Definitive Positions 1875.0.

	Mg.	α_{1875}	$\frac{da}{dt}$	$\frac{d^2a}{dt^2}$	$\frac{(100)^2}{6}\frac{d^3a}{dt^3}$	μ	δ_{1875}	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{dt^2}$	$\frac{(100)^3}{6}\frac{d^3\delta}{dt^3}$	μ'	$\frac{A}{a}$	$\frac{A}{\delta}$
		h m s					° ′ ″						
1	4.7	5 40 30.887	+4.15302	+.0000600	—.027	—.00254	39 8 9.44	+ 1.6750	—.006037	—.032	—.0275	I	22
2	5.7	5 43 57.841	+4.17116	+ 528	—.028	—.00137	39 32 22.49	+ 1.3837	— 6077	—.026	—.0180	5	5
3	6.9	5 50 32.250	+4.19906	+ 374	—.029	+.00588	40 1 5.87	+ 0.8351	— 6115	—.013	+.0077	5	5
4	7.0	5 58 7.259	3.90742	+ 188	—.020	+.00025	32 0 13.30	+ 0.1637	— 5700	+.002	—.0007	4	4
5	7.3	6 1 46.866	4.54812	+ 65	—.043	—.00437	47 55 39.31	— 0.1893	— 6640	+.011	—.0334	7	7
6	7.0	6 8 52.560	4.19113	— 75	—.028	+.00257	39 53 56.14	— 0.8009	— 6102	+.023	—.0245	3	3
7	7.4	6 13 10.900	4.38178	— 253	—.036	+.00018	44 27 57.11	— 1.1483	— 6376	+.035	+.0041	7	7
8	7.2	6 14 50.114	4.02707	— 159	—.023	+.00106	35 34 42.35	— 1.3208	— 5854	+.031	—.0238	5	5
9	8.0	6 17 24.853	4.19374	— 286	—.028	+.00374	39 59 44.47	— 1.5648	— 6087	+.039	—.0427	5	5
10	7.5	6 17 54.639	4.18222	— 293	—.028	+.00241	39 44 31.88	— 1.5883	— 6071	+.040	—.0230	4	4
11	7.5	6 20 9.528	4.19541	— 357	—.028	—.00140	40 11 41.19	— 1.7853	— 6090	+.045	—.0240	7	7
12	5.8	6 30 6.769	4.18289	— 595	—.027	—.00113	40 0 25.67	— 2.6582	— 6030	+.064	—.0314	21	21
13	6.0	6 35 48.071	4.04107	— 607	—.023	+.00180	36 13 48.90	— 3.1196	— 5807	+.068	—.0006	8	9
14	5.8	6 37 43.685	4.33378	— 887	—.032	+.00193	43 41 57.26	— 3.1276	— 6224	+.085	+.1580	N	N
15	7.0	6 43 55.048	4.17626	— 924	—.026	+.00048	40 4 28.59	— 3.8473	— 5963	+.089	—.0288	6	6
16	6.2	6 48 49.667	4.07923	— 924	—.023	+.00295	37 33 16.92	— 4.2632	— 5793	+.092	—.0239	8	9
17	7.0	6 50 27.862	4.26435	— 1201	—.029	—.00189	42 28 49.28	— 4.3755	— 6054	+.108	+.0035	9	9
18	7.5	6 55 0.613	4.38059	— 1493	—.032	—.00063	45 14 36.42	— 4.8143	— 6187	+.125	—.0479	3	3
19	6.0	6 57 57.100	3.96283	— 990	—.019	—.00384	34 39 42.63	— 5.0758	— 5580	+.101	—.0600	19	F. O
20	7.3	7 3 53.389	4.49034	— 1960	—.035	+.00059	47 48 53.17	— 5.6080	— 6272	+.153	—.0911	4	5
21	6.8	7 5 0.313	3.87728	— 996	—.016	—.00180	32 10 20.05	— 5.6110	— 5408	+.106	—.0003	7	7
22	7.7	7 9 37.119	4.68847	— 2575	—.042	+.00065	51 43 2.79	— 6.0662	— 6499	+.185	—.0690	2	2
23	7.6	7 12 33.965	3.75991	— 951	—.013	+.00270	28 21 1.26	— 6.2444	— 5181	+.107	—.0018	6	6
24	7.3	7 15 56.954	4.01363	— 1411	—.019	+.00481	36 33 2.40	— 6.5669	— 5501	+.133	—.0438	6	6
25	7.1	7 18 6.711	4.26872	— 1957	—.026	+.00126	43 30 14.92	— 6.7280	— 5838	+.161	—.0262	11	12
26	7.3	7 21 30.227	4.07310	— 1654	—.020	—.00240	38 41 41.77	— 7.0653	— 5543	+.148	—.0847	7	7
27	7.9	7 25 5.706	4.17421	— 1939	—.022	+.00276	41 26 19.64	— 7.2868	— 5639	+.164	—.0125	6	6
28	7.0	7 29 20.013	4.07946	— 1841	—.019	+.00086	39 9 19.03	— 7.6362	— 5470	+.161	—.0177	8	8
29	7.4	7 30 49.781	4.14338	— 2016	—.020	+.00149	40 57 7.92	— 7.7621	— 5540	+.170	—.0227	3	3
30	7.2	7 41 44.437	4.08824	— 2152	—.017	+.00059	40 4 56.00	— 8.6697	— 5347	+.182	—.0588	4	4
31	7.8	7 46 31.094	4.07929	— 2235	—.016	+.00350	40 2 17.65	— 9.0431	— 5276	+.188	—.0566	4	4
32	7.0	7 56 15.501	4.05135	— 2409	—.014	—.00399	40 5 26.78	— 9.7525	— 5128	+.200	—.0128	8	8
33	7.4	12 22 38.061	2.90504	— 2888	+.028	—.00792	50 19 35.99	—19.9397	+ 505	+.142	+.0116	4	6
34	7.3	12 25 38.473	2.98181	— 1280	+.014	—.00389	30 0 17.87	—19.9472	+ 572	+.152	—.0235	7	7
35	7.3	12 32 36.652	2.85713	— 2236	+.022	—.01912	45 54 21.37	—19.8837	+ 671	+.133	—.0373	9	9
36	7.0	12 36 15.057	2.90914	— 1398	+.015	—.01869	34 22 41.30	—19.9201	+ 748	+.140	—.1214	16	17
37	7.8	12 40 48.290	2.80929	— 2283	+.023	+.00084	48 3 21.73	—19.7599	+ 810	+.126	—.0279	5	5
38	7.5	12 44 57.576	2.90388	— 1200	+.014	—.00419	32 9 29.90	—19.7064	+ 911	+.140	—.0419	6	6
39	6.4	12 49 13.739	2.75421	— 2091	+.022	—.00263	47 52 30.06	—19.6028	+ 941	+.119	—.0145	10	12
40	6.8	12 54 27.441	2.87389	— 1110	+.014	+.00209	32 27 13.80	—19.5009	+ 1070	+.134	—.0152	16	16
41	6.3	12 58 10.874	2.75223	— 1665	+.018	+.00091	43 40 45.16	—19.4006	+ 1091	+.118	+.0058	11	11
42	5.6	12 59 53.664	2.81504	— 1251	+.015	—.00159	36 28 5.44	—19.3718	+ 1144	+.126	—.0036	N	N
43	7.8	13 3 59.586	2.59959	— 1984	+.022	—.00377	51 49 20.25	—19.3149	+ 1130	+.100	—.0424	2	2
44	4.1	13 6 2.350	2.80589	— 778	+.012	—.05964	28 30 44.13	—18.3498	+ 1219	+.124	+.8726	N	N
45	7.3	13 17 49.053	2.69106	— 1178	+.014	—.00618	40 4 55.90	—18.8898	+ 1392	+.110	+.0146	7	7
46	6.2	13 25 50.260	2.61043	— 1162	+.014	—.00943	42 44 59.27	—18.6468	+ 1478	+.100	+.0123	20	20
47	7.3	13 26 45.859	2.69300	— 950	+.013	—.00032	37 27 43.99	—18.6305	+ 1532	+.109	—.0011	12	14
48	7.7	13 35 6.046	2.52340	— 1100	+.014	+.00220	45 37 17.07	—18.3808	+ 1562	+.090	—.0333	5	5
49	7.5	13 40 32.601	2.67029	— 686	+.011	—.00866	34 41 11.05	—18.1449	+ 1738	+.106	+.0055	7	7
50	6.8	13 50 34.556	2.55027	— 724	+.011	+.00018	40 4 35.63	—17.7870	+ 1802	+.091	—.0267	9	9
51	7.6	14 5 15.403	2.48544	— 538	+.010	—.00107	40 7 6.76	—17.1794	+ 1959	+.084	—.0510	6	6
52	8.5	14 16 33.694	2.43671	— 405	+.008	—.00257	40 8 26.04	—16.4990	+ 2068	+.079	+.0949	4	4
53	7.3	14 23 54.581	2.40665	— 323	+.008	—.00221	40 10 36.65	—16.2209	+ 2134	+.075	+.0037	10	10
54	5.0	14 29 14.273	2.61394	— 150	+.006	+.01527	30 17 20.78	—15.8285	+ 2392	+.090	+.1179	N	N
55	6.0	14 30 17.399	2.09810	— 177	+.007	—.00543	49 54 50.77	—15.8458	+ 1926	+.056	+.0446	18	19
56	7.2	14 37 36.095	2.42482	— 156	+.006	—.00099	37 17 24.07	—15.5613	+ 2312	+.075	—.0689	14	F. O.
57	7.2	14 40 46.803	2.26272	— 160	+.006	—.00733	42 54 27.35	—15.2531	+ 2203	+.064	+.0614	15	F. O.
58	7.7	14 50 40.626	2.31145	— 60	+.005	+.00402	40 9 32.42	—14.7224	+ 2344	+.065	+.0192	7	7
59	6.5	14 54 38.320	2.29336	— 27	+.005	—.00032	40 8 31.75	—14.4656	+ 2372	+.064	+.0389	11	12
60	5.5	15 1 17.457	1.98620	+ 187	+.003	—.00631	48 38 5.21	—14.0797	+ 2110	+.049	+.0171	24	26

DEFINITIVE POSITIONS 1875.0.—*Continued.*

	Mg.	α_{1875}	$\frac{d\alpha}{dt}$	$\frac{d^2\alpha}{dt^2}$	$\frac{(100)^3}{6}\frac{d^3\alpha}{dt^3}$	μ	δ_{1875}	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{dt^2}$	$\frac{(100)^3}{6}\frac{d^3\delta}{dt^3}$	μ'	$\frac{A}{\alpha}$	$\frac{A}{\delta}$
		h m s					° ′ ″						
61	7.7	15 8 40.997	+1.94106	+.0000268	+.002	—.00127	49 2 52.13	—13.5901	+.002136	+.047	+.0396	10	9
62	5.3	15 17 59.935	2.21699	+ 145	+.003	—.00119	40 1 43.02	—13.0338	+ 2516	+.056	—.0129	14	16
63	7.2	16 43 15.891	2.09159	+ 360	000	—.00169	37 46 58.45	— 6.6199	+ 2912	+.030	—.0317	6	7
64	7.7	16 47 8.778	1.91719	+ 415	—.001	+.00021	42 17 24.87	— 6.2288	+ 2683	+.026	+.0375	8	7
65	7.8	16 51 12.060	1.99898	+ 380	—.001	+.00063	40 3 22.08	— 5.9704	+ 2810	+.026	—.0419	5	5
66	7.0	16 56 52.471	1.72901	+ 475	—.002	—.01279	45 57 37.60	— 5.4036	+ 2468	+.022	+.0489	2	2
67	7.7	17 0 15.694	1.75299	+ 460	—.002	+.00097	45 37 23.81	— 5.1897	+ 2491	+.021	—.0229	2	2
68	6.8	17 6 24.106	1.98459	+ 361	—.001	+.00396	40 0 21.44	— 4.6185	+ 2830	+.020	+.0276	3	3
69	7.5	17 12 43.139	2.26482	+ 307	—.001	—.00050	31 39 14.98	— 4.1335	+ 3252	+.021	—.0266	3	3
70	6.7	17 17 11.197	1.61808	+ 465	—.002	+.02096	48 18 48.40	— 3.7585	+ 2305	+.016	—.0349	4	5
71	6.5	17 21 0.428	2.40274	+ 291	—.001	+.00173	26 59 17.77	— 3.3738	+ 3466	+.019	+.0208	7	7
72	6.4	17 22 38.871	1.31766	+ 560	—.003	—.01026	52 54 4.05	— 3.3082	+ 1925	+.016	—.0550	5	5
73	6.1	17 26 29.698	2.00205	+ 312	—.001	+.00010	38 58 36.40	— 2.9075	+ 2901	+.013	+.0131	10	F. O.
74	6.5	17 30 41.088	1.92145	+ 321	—.002	+.00162	40 59 28.15	— 2.5340	+ 2788	+.012	+.0235	8	8
75	7.1	17 35 47.435	1.77990	+ 332	—.002	—.00537	44 4 4.68	— 2.0649	+ 2598	+.010	+.0491	8	8
76	7.9	17 36 49.202	2.11807	+ 279	—.001	+.00531	35 48 5.66	— 2.0408	+ 3074	+.010	—.0166	2	2
77	7.5	17 43 54.360	1.95008	+ 255	—.002	—.00226	40 1 8.08	— 1.2872	+ 2840	+.006	+.1196	12	12
78	5.0	17 49 13.959	1.95151	+ 253	—.001	+.00124	40 1 57.27	— 0.9011	+ 2847	+.005	+.0405	23	24
79	7.0	17 54 15.885	2.11645	+ 243	—.001	+.00269	35 38 32.50	— 0.5030	+ 3084	+.003	—.0013	6	5
80	6.5	17 58 49.839	1.76807	+ 260	—.002	—.00249	44 14 2.59	— 0.1474	+ 2582	+.003	—.0452	7	7
81	7.4	18 3 55.641	1.94698	+ 227	—.001	—.00735	39 54 12.31	+ 0.3796	+ 2848	000	+.0360	7	7
82	6.5	18 13 8.913	1.90134	+ 183	—.002	—.01511	40 53 18.17	+ 1.2163	+ 2723	—.002	+.0668	18	F. O.
83	7.9	18 15 36.924	1.99039	+ 197	—.001	—.00018	39 2 16.00	+ 1.3418	+ 2890	—.004	—.0232	4	4
84	8.4	18 24 13.665	1.95983	+ 174	—.001	—.00003	39 55 2.74	+ 2.0847	+ 2833	—.007	—.0308	6	6
85	7.7	18 35 36.982	1.96594	+ 157	—.001	+.00231	40 0 20.77	+ 3.0193	+ 2816	—.011	—.0840	4	4
86	7.6	18 45 23.160	2.03892	+ 135	—.001	+.00141	38 17 2.30	+ 3.9608	+ 2896	—.016	+.0163	7	6
87	7.7	18 47 52.008	1.91215	+ 111	—.001	+.00073	41 35 19.64	+ 4.1673	+ 2709	—.014	+.0103	5	5
88	7.0	18 52 45.989	2.11650	+ 131	—.001	+.00071	36 18 15.91	+ 4.5769	+ 2985	—.019	+.0016	8	9
89	7.4	18 55 15.938	1.83646	+ 75	—.001	—.00164	43 32 54.70	+ 4.8143	+ 2583	—.016	+.0261	5	5
90	8.0	18 59 52.935	1.98935	+ 103	—.001	—.00169	39 55 52.45	+ 5.1410	+ 2783	—.020	—.0382	8	8
91	7.4	19 2 21.420	2.13624	+ 122	000	—.00248	35 56 5.79	+ 5.3772	+ 2981	—.023	—.0107	12	12
92	7.7	19 4 18.453	1.83881	+ 53	—.001	+.00019	43 50 16.61	+ 5.5505	+ 2553	—.019	—.0018	5	5
93	7.9	19 11 6.181	2.00895	+ 92	000	+.00112	39 53 42.98	+ 6.1046	+ 2762	—.024	—.0164	7	6
94	7.3	19 8 12.235	1.96328	+ 84	—.001	+.00334	41 1 42.93	+ 5.8242	+ 2708	—.022	—.0547	3	4
95	7.2	19 12 52.366	2.05431	+ 99	000	+.00338	38 48 14.08	+ 6.2913	+ 2814	—.025	+.0232	9	9
96	6.6	19 17 3.315	1.91727	+ 58	—.001	—.00031	42 27 11.29	+ 6.5959	+ 2612	—.024	—.0187	7	8
97	6.0	19 18 17.058	2.11064	+ 107	000	—.00040	37 20 28.80	+ 6.7194	+ 2872	—.028	+.0035	5	6
98	7.1	20 50 41.182	2.25511	+ 365	+.004	+.00269	39 49 23.58	+13.5892	+ 2357	—.058		3	3
99	7.8	20 57 10.179	2.27624	+ 410	+.005	+.00203	39 49 11.01	+14.0102	+ 2314	—.060	+.0095	3	3
100	7.9	21 2 4.284	2.30067	+ 447	+.005	+.00958	39 49 4.98	+14.2691	+ 2280	—.062	—.0354	2	2
101	6.6	21 16 8.530	2.33858	+ 599	+.006	—.00263	39 49 21.02	+14.9042	+ 2174	—.067	—.2351	7	7
102	7.5	21 23 59.533	2.37167	+ 636	+.007	+.00160	39 50 17.14	+15.5828	+ 2108	—.071	+.0022	5	5
103	7.0	21 27 54.786	2.38878	+ 674	+.007	+.00419	39 51 17.67	+15.7800	+ 2074	—.072	—.0142	5	5
104	5.0	21 31 56.403	2.40038	+ 714	+.008	+.00019	39 51 9.77	+16.0199	+ 2039	—.074	+.0112	N	N
105	7.9	21 40 38.329	2.39051	+ 825	+.009	—.00365	41 35 25.91	+16.3990	+ 1924	—.074	—.0563	2	2
106	6.2	21 43 18.008	2.48679	+ 806	+.008	+.00295	38 4 6.08	+16.5781	+ 1964	—.082	—.0090	9	10
107	7.0	21 47 11.879	2.26213	+ 936	+.010	—.00116	47 51 1.72	+16.7822	+ 1735	—.066	+.0060	5	5
108	6.8	21 49 25.619	2.62664	+ 723	+.008	+.00089	31 44 53.33	+16.8821	+ 1993	—.096		3	3
109	7.8	21 54 24.930	2.73050	+ 601	+.008	+.00103	26 11 5.91	+17.1344	+ 2000	—.108	+.0209	10	10
110	7.3	21 55 34.280	2.13610	+ 1011	+.011	—.00226	53 30 31.86	+17.1495	+ 1537	—.059	—.0165	5	5
111	7.0	21 59 3.073	2.64595	+ 823	+.009	+.00019	32 20 11.13	+17.3219	+ 1869	—.100	+.0006	9	9
112	7.2	22 3 44.514	2.37050	+ 1201	+.012	+.00284	47 19 20.45	+17.5075	+ 1602	—.075	—.0168	15	15
113	7.7	22 8 55.686	2.55460	+ 1135	+.011	+.00275	39 51 53.46	+17.7389	+ 1658	—.092	—.0013	5	5
114	7.5	22 13 22.294	2.75512	+ 815	+.010	+.00507	28 13 14.36	+17.9435	+ 1722	—.113	+.0256	7	7
115	7.8	22 15 1.069	2.34660	+ 1445	+.015	+.01461	51 22 48.38	+17.9282	+ 1427	—.073	—.0540	2	2
116	7.8	22 21 7.060	2.68464	+ 1161	+.012	+.02082	36 7 49.40	+18.3098	+ 1546	—.104	+.0981	6	7
117	6.7	22 22 43.562	2.55213	+ 1428	+.014	+.00228	43 28 57.45	+18.2767	+ 1453	—.092	+.0066	8	8
118	7.7	22 27 34.223	2.62165	+ 1408	+.014	+.00108	40 42 26.87	+18.4162	+ 1421	—.100	—.0244	2	2
119	7.5	22 29 54.033	2.65754	+ 1377	+.013	—.00059	38 56 21.59	+18.5152	+ 1406	—.105	—.0043	16	17
120	7.0	22 33 48.919	2.66503	+ 1467	+.014	+.00431	39 57 0.91	+18.6042	+ 1345	—.105	—.0439	5	5

DEFINITIVE POSITIONS 1875.0.—*Continued.*

	Mg.	α_{1875}	$\frac{d\alpha}{dt}$	$\frac{d^2\alpha}{dt^2}$	$\frac{(100)^3}{6}\frac{d^3\alpha}{dt^3}$	μ	δ_{1875}	$\frac{d\delta}{dt}$	$\frac{d^2\delta}{dt^2}$	$\frac{(100)^3}{6}\frac{d^3\delta}{dt^3}$	μ'	$\frac{A}{\alpha}$	$\frac{A}{\delta}$
		h m s					° ′ ″						
121	5.7	22 35 53.004	+2.67457	+.0001478	+.014	—.00090	39 34 22.61	+18.7081	+.001318	—.107	—.0056	B	B
122	7.7	22 44 1.388	2.71536	+ 1608	+.015	+.00667	39 51 19.28	+18.9394	+ 1204	—.112	—.0179	7	7
123	5.8	22 48 23.236	2.74034	+ 1656	+.015	+.00975	39 42 39.19	+19.1279	+ 1140	—.115	+.0499	13	D
124	6.6	22 55 5.944	2.77925	+ 1670	+.015	—.00044	38 2 14.84	+19.2233	+ 1050	—.122	—.0272	9	9
125	7.6	22 57 28.564	2.79445	+ 1681	+.015	+.00019	37 37 36.32	+19.2591	+ 1015	—.123	—.0484	7	7
126	6.8	23 3 59.532	2.81239	+ 1831	+.016	+.00046	38 47 30.57	+19.4238	+ 909	—.126	—.0295	9	9
127	7.8	23 7 19.527	2.81381	+ 1994	+.017	+.00480	40 48 12.61	+19.4615	+ 849	—.126	—.0603	2	2
128	6.6	23 11 24.214	2.80496	+ 2290	+.020	+.00937	44 29 2.59	+19.5257	+ 774	—.124	—.0743	9	10
129	6.6	23 13 22.602	2.88264	+ 1745	+.015	+.00086	35 8 31.46	+19.6262	+ 765	—.136	—.0094	12	11
130	6.9	23 20 25.667	2.88091	+ 2124	+.018	—.00027	39 42 18.56	+19.5731	+ 637	—.137	—.1778	5	5